Maximum temperature attainable by thermite reaction

Asked 7 years, 3 months ago Active 1 year, 11 months ago Viewed 15k times

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In the thermite reaction

$$2\,\mathrm{Al(s)} + \mathrm{Fe_2O_3\,(s)} \longrightarrow 2\,\mathrm{Fe(l)} + \mathrm{Al_2O_3\,(s)}$$
$$2Al(s)+FeX2OX3(s)⟶2Fe(l)+AlX2OX3(s)$$

what is the maximum temperature attainable by the products? Assume reactants at 25 °C25 ∘C and 1 atm 1 atm and that all heat capacities remain constant.

I started by using Hess's law to find the enthalpy change of the reaction. I couldn't find a heat of formation for liquid iron so I assume I have to find that out. I just wrote out the equation

$$\mathrm{Fe(s)} + \text{heat} + \text{enthalpy of fusion} \longrightarrow \mathrm{Fe(s)}$$
$$Fe(s)+heat+enthalpy\ of\ fusion⟶Fe(s)$$

and figured the heat of formation for liquid iron at 25 °C25 ∘C is around −302.71 kJ/mol −302.71 kJ/mol.

To find the max temperature I used

$$\Delta H_r = \Delta T \cdot C_p(\text{products})$$
$$\Delta Hr=\Delta T\cdot Cp(products)$$

and came out with an equation like

$$-14445\ \mathrm{kJ/mol} = 0.147\ \mathrm{kJ/(mol\ K)} \cdot T_{max}$$
$$-14445\ kJ/mol=0.147\ kJ/(mol\ K)\cdot Tmax$$

This gives me a negative temperature, so I assume it is wrong. Even if I were to take the absolute value, the answer seems awfully high. I was expecting something around a few thousand degrees not near ten thousand.

physical-chemistry thermodynamics

edited Feb 25 '18 at 8:02
Gaurang Tandon
7,399 8 35 79

asked Oct 27 '12 at 22:46
Steve
111 1 1 3

Thermodynamics will never give a complete picture here: the actual heat will be dominated by the kinetics of the reaction and the kinetics of heat transfer to the environment. Thermodynamic calculations will give an absolute upper limit at best. – matt_black Oct 30 '12 at 19:58

4 Answers

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According to Wikipedia the maximum temperature is approximately 2500 °C, limited by the boiling point of aluminum, which is 2519 °C. The article provides some discussion of how the temperature is limited, and how to calculate it using Hesse's law.

edited Oct 30 '12 at 21:30
F'x
21.7k 6 80 139

answered Oct 28 '12 at 22:50
Mark
41 1

2

> This gives me a negative temperature, so I assume it is wrong.

Remember that the energy given off as an exothermic reaction progresses is absorbed by the surroundings. The chemical potential energy stored in aluminum and rust is converted into kinetic energy. You are interested in ΔH_{surr} ΔHsurr, which should be $-\Delta H_{sys}$ −ΔHsys. The "system" in this case is the electrons of the materials engaged in various bonding patterns, and the "surroundings" are the bulk materials.

> I was expecting something around a few thousand degrees not near ten thousand.

I would agree. Both aluminum oxide and iron melt and then boil below 10000 °C. Are you sure you are determining the $\Delta_f H^\circ$ ΔfHo of Fe(l) Fe(l) correctly? Melting is an endothermic process (absorbs heat from the surroundings).

answered Oct 28 '12 at 22:39
Ben Norris
37.4k 7 96 156

well for one I used a ridiculous number for the melting point of iron. That combined with fixing what is negative and what is not in each circumstance I am getting around 5000C which is more reasonable but still seems high. I could have just made another simple error – Steve Oct 29 '12 at 3:50

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> I am coming out with an equation like -14445 kJ/mol = 0.147 kJ/(mol K) * maxT

It is wrong. C_pCp is temperature dependent, so you have to use a more sophisticated equation with integrals. Moreover, parts for heating liquid and solid phases will be different.

answered Oct 29 '12 at 7:49
permeakra
19.2k 1 42 89

This question is assuming Cp is not temperature dependent in the given temperature ranges – Steve Oct 29 '12 at 12:18

1 Well... It is wrong. And again, one have to count at least the fact, that the reaction gives partially melted products, that also reduces overall effect. – permeakra Oct 29 '12 at 15:20

-3

There are many different types of thermite compositions although the cheapest form is aluminium based, while you could have magnesium, titanium, zinc, silicon and boron as the fuels source. The oxidzers can also vary from bismuth (III) oxide, boron (III) oxide, silicon (IV) oxide, Chromium (III) oxide, manganese (IV) oxide, iron (III) oxide,iron(I,III) oxide, copper (II) oxide or lead (II, IV) oxide.

Most thermite compositions burn at around 4,000 degrees, however once started the reaction can't be stopped until all the fuel and oxidizers have been spent.